California. This becomes reasonable when one considers the great difference in normal pressure existing between the Pacific Ocean off California and the interior of California and the lower Colorado valley. All the minor disturbances of the summer months are lost on the slope of this great baric gradient.

Seven high-pressure areas were charted, three of the so-called North Pacific type and two each of the Alberta and Hudson Bay types.

FREE-AIR SUMMARY.

By L. T. SAMUELS, Meteorologist.

A noticeable feature of the mean free-air temperatures for the month was the difference in their variation from the normal over the various sections of the country. (See Table 1.) This characteristic was also pronounced at the surface as is shown by the Climatological Chart III. At most stations the departures did not change appreciably with increasing altitude. At Drexel, however, a consistent change from negative to positive occurred, becoming greatest at the highest level. This relation conforms closely with the increasing southerly component in the resultant wind found at that station from the surface to the highest altitude. (See Table 2.) During the heat waves which prevailed in the latter half of the month it was found that the free-air temperatures were, as a rule, proportionally high with respect to their normals, and in practically every case deep southerly winds prevailed from the surface to the highest levels.

Relative humidities averaged mostly in excess of their normals but the departures were practically all less than 10 per cent except in the highest levels where the observations are as yet too deficient in number to obtain reliable normals. The vapor pressures also averaged mostly above their normals for all stations except Ellendale.

In Table 2 are shown the resultant wind velocities and directions for the month and their normals. At Ellendale, Drexel, and Due West the southerly component exceeded the normal amount as did the resultant velocities at these stations. At the other stations, however, there was but little difference between the means and the normals.

At this season of the year, owing in part to the increase in the number of daylight hours in the higher latitudes, the horizontal temperature gradient from the equatorial to the polar regions becomes decidedly smaller than exists in winter. This condition results in an abatement of the strong upper winds characteristic of the latter season and instead these winds frequently continue extremely light to great heights. In fact, easterly winds are often then found to extend to the stratosphere. In general these conditions occur most frequently at the southern stations as is found this month. As an illustration of an exceptionally light wind extending from the surface to 9,000 meters above, the pilot-balloon observation of the 22d from Royal Center is cited. This velocity varied from practically calm to 3 m. p. s. but never exceeded this amount even to this height. At Broken Arrow on the same day the balloon was followed with two theodolites to a height of 9,600 meters and from that altitude by one theodolite to 20,300 meters. The wind was south from the surface to 10,000 meters where a shift to west and northwest occurred, remaining so to 15,000 meters, above which it backed steadily becoming southeast at the highest altitude. The velocity at the surface was 9 m. p. s. decreasing to practically calm at 10,000 meters where the shift occurred, then increasing sharply to 16 m. p. s. at 12,000 meters, above which it averaged about 10 m. p. s.

An unusually high two-theodolite observation was obtained at Groesbeck on the 6th when the balloon was followed for 67 minutes reaching a height of 13,000 meters. Strong winds of 30 m. p. s. from the northwest were found at this high altitude.

The morning kite flight at Broken Arrow on the 6th was completed just as a thunderstorm broke at that station. The storm lasted about one hour and a second kite flight was made immediately after the rain stopped. Both flights attained slightly more than 3,500 meters' altitude and are, therefore, of special interest since they show the free-air conditions just preceding and following a typical convection thunderstorm. The general wind drift at the surface was from the south but during the storm this changed to northerly becoming southerly again immediately after the storm. The temperature lapse-rate off the surface during the morning nearly equalled the adiabatic rate for dry air, indicating conditions favorable for convection and supporting thunderstorm development. The winds above 1,000 meters had a greater west component after the storm than they had before and were of a slightly higher velocity. The other elements such as temperature, relative humidity and vapor pressure resumed practically their former state. There was discernible, however, in the second flight a consistently higher temperature to 2,500 meters and a correspondingly lower relative humidity. The small change in the free-air conditions would be expected, since the thunderstorm, originating in some other locality, was merely carried over Broken Arrow by the upper wind and once having passed, the elements would quickly resume their former state.

The following pertinent note by the official in charge of the Drexel station relative to a series of kite flights made on the 20th and 21st is of interest in connection with flights made during thunderstorm conditions:

> The weather was generally cloudy and at times threatening during the daylight hours and for the most part clear in the night. Lines of showers passed the station at intervals to the east and the west moving from south to north. Eventually light showers passed over the station during the last flight, thunder began immediately after the flight, and a light drizzling rain set in a few hours later. The showers evidently were the development of clouds of a convectional nature as a characteristic of the weather throughout the week has been cloudy and threatening weather by day and generally clear weather at night.

A decidedly large lapse rate as well as generally high humidity was apparent throughout the entire series. The general wind direction during the series remained mostly south from the surface to the highest levels reached (3,500 meters). The velocities aloft showed an appreciable increase as the series progressed. The temperature above the surface showed practically no change during the series and the moisture content varied with the changes in cloudiness.

The following from Broken Arrow appearing on the kite flight of the 6th is of interest:

> Large oil fire at West Tulsa; smoke topped by cumulus cloud. Fire started by thunderstorm during morning.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during June, 1923.*

TEMPERATURE (°C.).

Altitude, m. s. l. (meters).	Broken Arrow, Okla. (233 meters.)		Drexel, Nebr. (396 meters.)		Due West, S. C. (217 meters.)		Ellendale, N. Dak. (444 meters.)		Groesbeck, Tex. (141 meters.)		Royal Center, Ind. (225 meters.)	
	Mean.	Departure from 5-year mean.	Mean.	Departure from 8-year mean.	Mean.	Departure from 3-year mean.	Mean.	Departure from 6-year mean.	Mean.	Departure from 5-year mean.	Mean.	Departure from 5-year mean.
Surface..	24.8	+0.2	20.7	−0.9	27.1	+0.5	19.8	0.0	26.8	+1.0	23.4	−0.2
250.....	24.7	+0.2	.....	.....	26.7	+0.5	.....	.....	25.7	+0.8	23.1	−0.2
500.....	22.9	+0.4	20.0	−0.9	23.9	+0.5	19.6	+0.1	23.4	+0.4	20.3	−0.3
750.....	21.3	+0.5	18.6	−0.7	21.7	+0.2	18.1	+0.1	21.8	+0.3	18.0	−0.6
1,000.....	19.9	+0.5	17.7	−0.3	19.8	−0.1	16.4	−0.3	20.5	+0.3	16.0	−1.0
1,250.....	18.7	+0.7	16.5	−0.1	17.9	−0.4	15.0	−0.5	19.3	+0.4	14.3	−1.2
1,500.....	17.4	+0.9	15.2	−0.1	16.0	−0.6	13.9	−0.4	18.3	+0.7	12.9	−1.1
2,000.....	14.5	+1.0	12.8	+0.3	12.5	−0.8	11.1	−0.3	16.1	+1.0	10.5	−0.8
2,500.....	11.4	+0.7	10.5	+1.0	9.2	−0.9	8.5	0.0	13.7	+1.2	8.1	−0.4
3,000.....	8.4	+0.7	7.7	+1.2	6.5	−0.7	5.9	+0.2	11.2	+1.2	5.0	−0.7
3,500.....	5.3	+0.7	4.7	+1.5	3.8	−0.3	3.0	+0.2	8.4	+1.1	2.1	−0.9
4,000.....	2.2	+0.6	1.8	+1.9	1.6	+0.3	−0.2	−0.1	5.6	+0.9	−0.9	−1.5
4,500.....	−2.0	−0.4	−1.0	+2.0	−1.0	−0.1	−3.2	+0.1	.....	.....	−4.1	−2.1
5,000.....	.....	.....	−3.8	+2.6	.....	.....	−6.0	+0.1	.....	.....	.....	.....

RELATIVE HUMIDITY (%).

Surface..	77	+3	80	+11	60	−2	69	−3	71	−3	66	+4
250.....	77	+3	.....	.....	60	−3	.....	.....	74	−1	67	+5
500.....	77	+3	78	+10	64	−2	68	−3	79	+3	71	+7
750.....	77	+3	75	+9	67	0	67	−2	79	+4	74	+8
1,000.....	76	+3	72	+7	69	+1	69	+1	76	+4	74	+7
1,250.....	72	0	72	+7	70	+2	69	+3	72	+3	74	+7
1,500.....	68	−2	72	+9	71	+3	64	0	67	+1	71	+5
2,000.....	66	−1	69	+9	75	+6	61	−1	59	−1	63	+1
2,500.....	64	+5	59	+1	78	+7	54	−5	54	−2	49	−3
3,000.....	60	+5	57	0	73	+5	46	−8	53	+2	48	0
3,500.....	60	+6	56	−1	67	+2	43	−8	52	+3	45	+4
4,000.....	58	+7	51	−5	57	+3	43	−6	52	+4	48	+19
4,500.....	72	+23	52	−1	58	+16	34	−17	.....	.....	52	+25
5,000.....	.....	.....	58	+2	.....	.....	35	−16	.....	.....	.....	.....

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressure during June, 1923*—Continued.

VAPOR PRESSURE (mb.).

Altitude, m. s. l. (meters).	Broken Arrow, Okla. (233 meters.)		Drexel, Nebr. (396 meters.)		Due West, S. C. (217 meters.)		Ellendale, N. Dak. (444 meters.)		Groesbeck, Tex. (141 meters.)		Royal Center, Ind. (225 meters.)	
	Mean.	Departure from 5-year mean.	Mean.	Departure from 8-year mean.	Mean.	Departure from 3-year mean.	Mean.	Departure from 6-year mean.	Mean.	Departure from 5-year mean.	Mean.	Departure from 5-year mean.
Surface..	24.28	+1.27	19.87	+1.82	21.22	+0.16	16.03	−0.78	24.69	+0.31	19.25	+1.01
250.....	24.11	+1.32	.....	.....	20.92	+0.19	.....	.....	24.12	+0.65	19.10	+1.08
500.....	21.66	+1.39	18.57	+1.72	18.80	+0.29	15.68	−0.62	22.58	+1.15	17.20	+1.36
750.....	19.44	+1.22	16.11	+1.37	17.27	+0.41	14.20	−0.10	20.58	+1.18	15.60	+1.14
1,000.....	17.52	+0.98	14.52	+1.07	15.84	+0.38	13.18	+0.33	18.25	+1.05	14.06	+0.77
1,250.....	15.06	+0.24	13.48	+1.26	14.44	+0.34	12.10	+0.57	16.10	+0.84	12.50	+0.35
1,500.....	13.30	+0.09	12.37	+1.51	13.09	+0.33	10.19	−0.02	14.01	+0.67	10.86	+0.01
2,000.....	10.67	+0.39	10.11	+1.47	10.91	+0.44	7.97	−0.26	10.90	+0.52	8.05	−0.11
2,500.....	8.28	+0.85	7.35	+0.49	8.99	+0.47	6.13	−0.51	8.58	+0.32	5.41	−0.02
3,000.....	6.20	+0.76	5.77	+0.21	6.98	+0.35	4.00	−0.98	7.27	+0.73	4.12	+0.30
3,500.....	4.94	+0.63	4.43	−0.05	5.22	+0.21	3.16	−0.85	6.07	+0.73	2.94	+0.62
4,000.....	3.89	+0.53	3.40	−0.23	3.66	+0.40	2.52	−0.80	4.99	+0.56	2.68	+1.91
4,500.....	3.61	+0.96	2.96	+0.19	3.12	+1.04	1.35	−1.42	.....	.....	2.54	+2.36
5,000.....	.....	.....	2.78	+0.55	.....	.....	1.26	−1.41	.....	.....	.....	.....

TABLE 2.—*Free-air resultant winds (m. p. s.) during June, 1923.*

Altitude, m. s. l.	Broken Arrow, Okla. (233 meters.)				Drexel, Nebr. (396 meters.)				Due West, S. C. (217 meters.)				Ellendale, N. Dak. (444 meters.)				Groesbeck, Tex. (141 meters.)				Royal Center, Ind. (225 meters.)			
	Mean.		5-year mean.		Mean.		8-year mean.		Mean.		3-year mean.		Mean.		6-year mean.		Mean.		5-year mean.		Mean.		5-year mean.	
	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.
(Meters).																								
Surface.....	S. 2° W.	4.2	S. 3° W.	3.8	S. 13° E.	3.3	S. 4° W.	1.7	S. 48° W.	2.4	S. 77° W.	0.8	S. 9° E.	1.7	S. 22° E.	0.4	S. 22° E.	3.9	S. 17° E.	2.9	S. 58° W.	2.6	S. 52° W.	1.3
250.....	S. 3° W.	4.3	S. 4° W.	3.9	.....	.....	.....	.....	S. 48° W.	2.4	S. 75° W.	0.9	.....	.....	.....	.....	S. 20° E.	4.8	S. 16° E.	3.5	S. 57° W.	2.6	S. 51° W.	1.3
500.....	S. 8° W.	5.9	S. 11° W.	5.2	S. 7° E.	5.1	S. 3° W.	2.3	S. 48° W.	2.8	S. 76° W.	1.3	S. 10° E.	1.9	S. 11° E.	0.6	S. 12° E.	6.9	S. 7° E.	4.8	S. 54° W.	3.8	S. 46° W.	2.2
750.....	S. 11° W.	6.6	S. 14° W.	5.9	S. 4° W.	8.3	S. 15° W.	3.5	S. 47° W.	3.4	S. 71° W.	2.0	S. 2° E.	3.3	S. 4° E.	1.3	S. 4° E.	7.2	S. 3° E.	5.2	S. 57° W.	5.0	S. 53° W.	2.9
1,000.....	S. 18° W.	6.5	S. 20° W.	6.1	S. 15° W.	8.5	S. 29° W.	4.1	S. 51° W.	3.6	S. 71° W.	1.9	S. 13° W.	4.1	S. 17° W.	1.8	S. 4° W.	7.1	S. 1° W.	5.5	S. 57° W.	5.7	S. 66° W.	3.4
1,250.....	S. 26° W.	6.2	S. 24° W.	6.1	S. 20° W.	8.8	S. 40° W.	4.3	S. 55° W.	4.4	S. 72° W.	2.3	S. 17° W.	4.4	S. 39° W.	2.2	S. 5° W.	7.6	S. 4° W.	6.0	S. 65° W.	5.5	S. 75° W.	3.7
1,500.....	S. 29° W.	5.9	S. 27° W.	6.2	S. 32° W.	8.6	S. 52° W.	5.0	S. 67° W.	5.4	S. 79° W.	3.2	S. 23° W.	4.6	S. 43° W.	2.6	S. 12° W.	7.2	S. 5° W.	5.4	S. 60° W.	5.9	S. 84° W.	4.1
2,000.....	S. 35° W.	5.7	S. 33° W.	6.3	S. 35° W.	8.6	S. 59° W.	6.0	S. 80° W.	7.3	S. 85° W.	5.1	S. 30° W.	4.5	S. 56° W.	3.5	S. 17° W.	6.9	S. 7° W.	5.1	S. 70° W.	7.7	S. 84° W.	6.2
2,500.....	S. 38° W.	5.7	S. 32° W.	6.4	S. 41° W.	10.5	S. 67° W.	7.1	S. 79° W.	6.1	S. 90° W.	5.1	S. 49° W.	5.6	S. 67° W.	5.3	S. 18° W.	6.8	S. 12° W.	5.1	S. 70° W.	8.6	S. 83° W.	8.2
3,000.....	S. 42° W.	6.5	S. 27° W.	6.4	S. 43° W.	10.8	S. 72° W.	8.5	S. 81° W.	7.8	S. 85° W.	6.8	S. 72° W.	7.6	S. 76° W.	7.3	S. 10° W.	6.3	S. 14° W.	5.4	S. 71° W.	8.8	S. 86° W.	10.2
3,500.....	S. 48° W.	8.2	S. 34° W.	7.8	S. 29° W.	11.3	S. 74° W.	9.1	S. 63° W.	9.7	S. 66° W.	7.8	S. 77° W.	8.7	S. 81° W.	8.4	S. 3° W.	6.3	S. 8° W.	6.4	S. 77° W.	8.8	S. 88° W.	12.3
4,000.....	S. 30° W.	9.8	S. 33° W.	8.1	S. 35° W.	8.4	N. 87° W.	8.2	S. 66° W.	11.9	S. 69° W.	10.1	N. 84° W.	12.3	N. 85° W.	10.5	S. 17° W.	7.6	S. 2° W.	7.2	N. 80° W.	4.5	W.	13.0
4,500.....	S. 32° W.	10.5	S. 46° W.	6.5	S. 16° W.	7.4	N. 77° W.	8.4	W.	17.7	N. 72° W.	12.2	S. 61° W.	9.6	N. 80° W.	12.1	S. 7° W.	7.2	S. 16° E.	9.3	N. 67° W.	11.3	S. 77° W.	7.1
5,000.....	W.	13.6	W.	13.6	N. 45° W.	18.1	N. 52° W.	18.8	.....	.....	.....	.....	N. 23° W.	15.9	N. 64° W.	16.2	.....	.....	.....	.....	N. 22° W.	23.7	N. 22° W.	23.7

THE WEATHER ELEMENTS.

By P. C. DAY, Meteorologist, in Charge of Division.

PRESSURE AND WINDS.

The atmospheric circulation during June, as in the preceding month, and as may be expected in the warmer months of the year, was without sudden and important variations, and cyclonic and anticyclonic activity were both at a low ebb during much of the month. While the pressure was frequently low over the Mountain and Plateau districts, the cyclonic disturbances originating there were mainly unable to advance far to the eastward on account of rather persistent, though moderate, anticyclonic conditions over the central valleys and southeastern districts.

One of the most important cyclones of the month, though not well defined, but accompanied by widespread precipitation, moved slowly from the western mountain regions eastward to the Atlantic coast during the middle part of the first decade. Heavy falls of rain accompanied this storm locally in the central valleys and parts of the East, though the Southern States had usually only scattered showers. As this disturbance was passing off the North Atlantic coast another rather important cyclone developed over the Southwest, and moved slowly eastward, reaching the Middle and South Atlantic coasts by the 13th. This was likewise attended by widespread precipitation, though the notably heavy falls were confined mainly to the districts from the central Plains eastward. At Wichita, Kans., a 24-hour fall of nearly